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Woody Diversity in Cult Places (Cemeteries, Mosques, and Parishes) in Ziguinchor City (Senegal)

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Abstract

Urban and peri-urban forests and trees play an important role by providing ecosystem services. Vegetation in sacred and cult places is among the useful forests and trees, but their characteristics are not well-documented. It's necessary to assess the potential of biodiversity conservation in sacred and cult places. This research aimed to enhance knowledge of the woody diversity in cult places in Ziguinchor. To achieve this, woody vegetation surveys were conducted to determine floristic composition and, diversity and structural parameters of woody vegetation. A total of 89 species belonging to 71 genera and 33 families were recorded, *Fabaceae* and *Moraceae* dominated in cemeteries and parishes, while *Arecaceae* and *Euphorbiaceae* were prevalent in mosques. Tree diversity varied according to cult places. Parishes recorded significatively higher diversity (2.2 ± 0.18) than cemeteries (1.59 ± 0.13) and mosques (1.07 ± 0.36). Cult places inflenced significatly the structural parameters. Tree density was higher in cemeteries (482.26 ± 302.71 indiv/ha) compared to parishes (197.61 ± 67.14 indiv/ha) and mosques (32.34 ± 4.89 indiv/ha). Mosques were characterized by higher canopy cover (25.43 ± 11.65 m^2/ha), larger (83.72 ± 20.09 cm) and taller (16.28 ± 1.28 m) trees. Natural regeneration was also strongest in cemeteries (91.69% ± 3.715%), followed by parishes (62.22% ± 8.56%) and mosques (38.82% ± 14.5%). The cult places play an important ecological role in biodiversity conservation in urban and peri-urban areas.

Keywords

Tree Diversity, Biodiversity Conservation, Cult Places

1. Introduction

Trees are an essential component of urban ecosystems [1]. Their presence in cities is associated with numerous benefits, including the reduction of air pollutants [2], mitigation of urban heat islands [3], and carbon dioxide reduction through carbon sequestration [4]. Additionally, trees contribute to erosion control, territorial delimitation, and land marking [5] [6]. In urban environments, trees also address social, ecological, and economic challenges [7] by providing shade and fulfilling food, energy, and health needs. Moreover, urban vegetation fosters social cohesion [8].

Woody biodiversity continues to suffer from both anthropogenic and natural degradation, particularly due to climate change in the Casamance region, despite regulations protecting the environment. However, deforestation is less evident in certain spaces—such as cemeteries, mosques, parishes, and sacred groves—due to the cultural and spiritual significance and respect these areas command. These places of worship, shaped by long historical processes, reflect strong and intimate relationships between humans and their environment [9].

In urban settings, forest formations often function as sacred spaces and serve as bastions for preserving biological diversity [10]. In this context, places of worship can play a crucial role in conserving plant diversity. Ziguinchor, a municipality in Casamance, hosts some of Senegal's most significant urban green lungs. Compared to the flora of other African cities, Ziguinchor retains an original plant diversity that warrants further attention for the valuable ecosystem services it provides to urban and peri-urban populations [11].

Currently, the management and conservation of biological resources have become major global concerns, especially as these resources are often in decline [12]. In Senegal, local community involvement in ecosystem management is increasingly recognized as imperative. Despite the numerous benefits trees provide to populations, their sustainability is threatened by intense anthropogenic pressure, climatic variability, and its consequences [13].

Despite its importance, the woody vegetation in Ziguinchor was faced to degradation caused by urban population growth [14]. Given the sociocultural and environmental importance of conserving this woody diversity, this research aimed to enhance knowledge about the woody vegetation diversity of cult places (mosques, parishes, and cemeteries) in Ziguinchor. Additionally, the aim of this work was to characterize woody vegetation diversity and compare the species richness among the different types of cult places.

2. Materials and Methods

2.1. Study Area Description

The study was conducted in cult places of Ziguinchor city. The research was carried out in four parishes (St. Antoine de Padoue, St. Augustin, Notre Dame and St. Benoit), four mosques (Kandé, Peace Mosque, Grand Dakar Mosque, and Kadior Mosque), and four cemeteries (Santiaba, Belfort, Kandialang, and Kénia)

(Figure 1). Ziguinchor was characterized by a southern coastal Sudanian climate [15] with an average annual rainfall of 1300 mm.

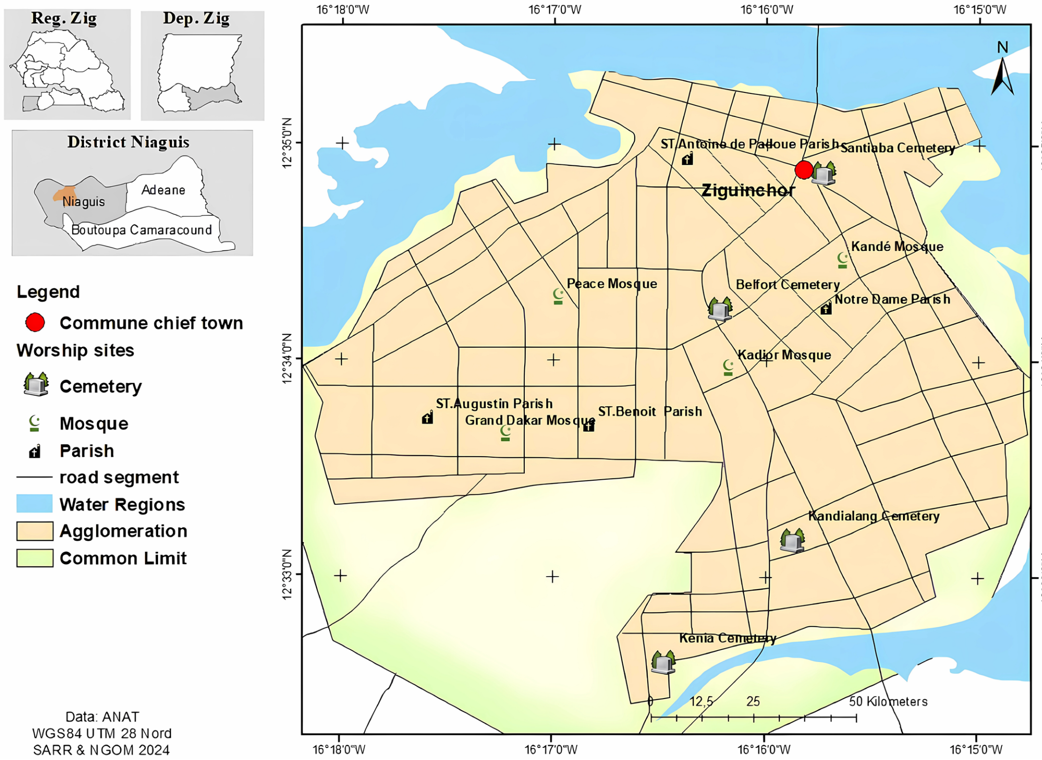

Figure 1. Location of cult places in Ziguinchor City.

2.2. Woody Vegetation Surveys

The survey of woody vegetation was based on an initial classification or stratification from the list of cult places. Three classes were cemeteries, mosques and parishes were considered. Site selection was based on stratified random sampling, considering their geographic distribution for comprehensive coverage of the municipality, their size, and the density of their woody diversity. Within each class of cult places, simple random sampling was used to select the cult places for the survey. The area of these sites ranges from 0.2 to 5 hectares. The study was conducted across 12 cult places in Ziguinchor. A total of four cemeteries, mosques and parishes were selected for the woody vegetation inventory. The geographic coordinates of each site were recorded using a Gar-min Dakota 10 GPS to to determine the total area. Within each cult place, a systematic inventory of woody species was carried out. For every adult tree, the geographic coordinates were recorded. Measurements included the diameter at breast height (DBH), the diameter, and height. Seedlings and saplings were also counted. Individuals with a DBH less than 5 cm, or young palm trees were classified as regenerations. Observations such as stumps, standing dead trees, felled trees, the presence of termite mounds, tree phenology, health conditions, and structural forms were also recorded. The floristic composition was established using vegetation survey sheets, with taxonomic identification based on floristic identification key [16]-[18].

2.3. Data Analysis

Inventory data were processed using Excel. Floristic diversity was measured using BiodiversityR package [19]. Statistical analysis, including analysis of variance, was performed using R (version 4.1.1) at a 5% significance level. Principal Component Analysis (PCA) and clustering based on Bray-Curtis ecological distance were conducted using ggplot2, factoextra and ggrepel packages in R. Tree diameter and height data were used to determine structural parameters distribution with a maximum likelihood-based algorithm [20] [21] implemented in Minitab 14 using the three-parameter Weibull distribution method [22].

Several diversity indices (species richness, Shannon, Pielou, Heip and Bray-Curtis) and vegetation parameters (density, basal area, canopy cover) were calculated.

- **Species Richness:** Total species richness (S) is the total number of species in the population of a given ecosystem [23]. Mean species richness represents the average number of species per survey [24].
- **Shannon-Weaver Diversity Index (H'):** This index accounts for species richness and the abundance of individuals within each species. The Shannon-Weaver Index ranges from 0 to lnS, approximately 4.5 for a relatively rich community [25]. It is calculated as:

$$H' = -\sum_{i=1}^{n} pi \ln pi$$

Where p is the relative abundance of species i.

- **Pielou's Evenness Index (J):** This measures the evenness of species distribution, calculated as:

$$J = \frac{H'}{H \max}$$

Where $H\max = \ln (S)$ is the maximum diversity.

- Heip's Evenness (E) was determined using the following formula:

$$E = e^{H'} / S$$

- Bray-Curtis (D) ecological distance between cult places was determined using the following formula:

$$D = 1 - 2\frac{\sum \min(ai, ci)}{\sum (ai + ci)}$$

- **Frequency Analysis:** This method assessed species distribution across surveys. Presence frequency, expressed as a percentage, was calculated using the following formula [24] [26]:

$$F = \frac{Nri}{Nr} \times 100$$

Where F is the frequency of occurrence, Nri is the number of surveys where species i is present, and Nr is the total number of surveys.

- **Observed density (Dobs)** is the number of individuals per unit area, expressed as individuals per hectare and was calculated as:

$$\text{Dobs} = \frac{N}{S}$$

Where Dobs is the observed density, N is the total number of individuals, and S is the sampled area (ha).

- **Canopy Cover (C)** expressed as m^2 per hectare, is the surface area of tree crowns projected vertically onto the ground and was calculated as:

$$C = \frac{\sum_{t=1}^{n} \pi \left(\frac{\text{dmh}}{2} \right)^2}{S_A}$$

Where C is the canopy cover, dmh is the mean canopy diameter (m), and S_A is the sampled area (ha).

- **Basal Area (BA)** represents the cross-sectional area of tree trunks at 1.3 m height, expressed in m^2 per hectare. It is calculated as:

$$BA_t = \frac{\sum_{t=1}^{n} \pi \left(\frac{d_{1,3}}{2} \right)^2}{S_A}$$

Where BA is the basal area, $d_{1.3}$ is diameter at breast height (DBH), and S_A is the sampled area (ha).

- **Regeneration Rate (RR)** is the percentage ratio of the total number of seedlings to the total population, calculated as:

$$RR = \frac{\text{Number of seedlings}}{\text{Total population}} \times 100$$

3. Results

3.1. Floristic Composition

A total of 89 woody vegetation species belonging to 71 genera and 33 families were recorded in cult places of Ziguinchor (Table 1). Among these species, 56 were characteristic species. Notably, only six species are common across all sites. The highest number of species (36) was recorded in parishes, followed by cemeteries (17) and mosques (3). Species richness varied significantly (p = 0.0117) between cult places (Figure 2). Parishes recorded significantly higher richness (27.25 ± 5.52) than mosques (5.75 ± 2.17).

In cemeteries, the most represented family was *Moraceae* (31.11%), followed by Fabaceae (15.55%). *Arecaceae* (14.29%) and *Euphorbiaceae* (14.29%) were the most important families in mosques. Parishes were dominated by *Fabaceae* (20.97%), followed by *Annonaceae*, *Arecaceae*, *Combretaceae*, and *Rutaceae with* 4.84%. *Elaeis guineensis* and *Azadirachta indica* are the most frequent species in cemeteries, with 100% frequency, followed by *Adansonia digitata*, *Anthostemasenegalense*, *Borassus* *akeassii*, *Ceiba pentandra*, and *Senna siamea* (75% each). In parishes, *Azadirachta indica*, *Borassus akeassii*, *Delonix regia*, and *Mangifera indica* are the most frequent (100%), while *Elaeis guineensis*, *Ceiba pentandra*, *Citrus limon*, *Cocos nucifera*, *Cola cordifolia*, and *Terminalia mantaly* follow with 75%. In mosques, *Mangifera indica* and *Cocos nucifera* are the most frequent, with 100% and 75% respectively.

Table 1. Floristic composition of cult places.

Family	Genus	Species	Cemeteries	Parishes	Mosques
Anacardiaceae	*Anacardium*	*Anacadium occidentale L.*	+	+	−
	Mangifera	*Mangifera indica L.*	+	+	+
Annonaceae	*Annona*	*Annona muricata L.*	−	+	−
		Annona squamosa L.	−	+	−
	Monoon	*Monoon longifolium (Sonn.) B. Xue & R.M.K Sauders*	−	+	−
Apocynaceae	*Calotropis*	*Calotropis procera Ait.*	−	+	−
	Holarrhena	*Holarrhena floribunda (G. Don) Dur. &Schinz*	+	+	−
Arecaceae	*Borassus*	*Borassus akeassii Bayton, Ouédraogo &Guinko*	+	+	−
	Cocos	*Cocos nucifera L.*	−	+	+
	Elaeis	*Elaeis guineensis Jacq.*	+	+	+
	Phoenix	*Phoenix dactylifera L.*	−	−	+
Begoniaceae	*Begonia*	*Begonia coralina*	+	−	−
Bignoniaceae	*Pandorea*	*Pandorea jasminoides (Lindl.) K. Schum*	+	+	−
	Tabebuia	*Tabebuia heterophylla (DC.) Britt.*	−	+	−
Bombacaceae	*Adansonia*	*Adansonia digitata L.*	+	+	+
	Ceiba	*Ceiba pentandra (L.) Gaertn.*	+	+	−
Boraginaceae	*Cordia*	*Cordia monoica Roxb.*	−	+	−
		Cordia sebestena L.	−	+	+
Caricaceae	*Carica*	*Caric apapaya L.*	−	+	−
Casuarinaceae	*Casuarina*	*Casuarina equisetifolia Forst.*	−	+	−
Chrysobalanaceae	*Parinari*	*Parinari excelsa Sabine.*	+	−	−
Combretaceae	*Combretum*	*Combretum micranthum G. Don*	+	+	−
	Guiera	*Guiera senegalensis J.F. Gmel*	+	−	−
	Terminalia	*Terminalia catappa L.*	−	+	−
		Terminalia mantaly Perr.	−	+	+

Continued

Euphorbiaceae	*Alchornea*	*Alchornea cordifolia (Schumach.) W. F. Wight*	+	−	−
	Anthostema	*Anthostema senegalense A. Juss.*	+	−	−
	Hura	*Hura crepitans L.*	−	+	+
	Jatropha	*Jatropha curcas L.*	+	+	−
	Ricnus	*Ricnus comminus L.*	−	+	−
Fabaceae	*Acacia*	*Acacia auriculiformis A.Cunn. exBenth.*	−	+	−
	Albizia	*Albizia harveyi Durazz.*	−	+	−
		Albizia lebbeck (L.) Benth.	−	+	−
		Albizia zygia (D. C.) J. F. Macbr.	−	+	−
	Delonix	*Deloni xregia (Boj.) Raf.*	+	+	−
	Detarium	*Detarium senegalense J. F. Gmel.*	+	−	−
	Erythrina	*Erythrina variegata L.*	−	+	−
	Faidherbia	*Faidherbia albida (Del.) Chev.*	+	+	−
	Gliricidia	*Gliricidia sepium (Jacq.) Kunth ex Walp.*	−	+	−
	Holocalyx	*Holocalyx balanseaMicheli.*	−	+	−
	Parkia	*Parkia biglobosa (jacq.) R. Br. ex G. Don*	−	+	−
	Piliostigma	*Piliostigma thonningii (Schumach.) Milne-Redh*	+	−	−
	Pongamia	*Pongamia pinnata (L.) Pierre*	+	−	−
	Pterocarpus	*Pterocarpus erinaceus Poir.*	+	−	−
	Senna	*Senna siamea Lam.*	+	+	−
	Tamarindus	*Tamarindus indica L,*	−	+	−
	Caesalpinia	*Caesalpinia pulcherrima (L.) Sw.*	−	+	−
Fagaceae	*Quercus*	*Quercus montana Willd.*	+	−	−
Icacinaceae	*Icacina*	*Icacina senegalensis Juss.*	+	+	−
Lauraceae	*Persea*	*Persea americana Mill.*	−	+	−
Meliaceae	*Azadirachta*	*Azadirachta indica A. Juss.*	+	+	+
	Carapa	*Carapa procera Dc.*	−	+	−
	Khaya	*Khaya senegalensis (Desr.) A. Juss*	+	+	−
Moraceae	*Artocarpus*	*Artocarpus altilis (Park.) Fosb.*	−	+	−
	Antiaris	*Antiaris Africana Engl.*	+	+	−
		Antiaris toxicaria Lesch.	−	+	−
	Artocarpus	*Artocarpus heterophyllus Lam.*	−	−	+

Continued

Moraceae	*Ficus*	*Ficus sycomorus L.*	+	+	−
		Ficus benjamina L.	+	−	−
		Ficus exasperate Vahl.	+	−	−
		Ficus insipida Willd.	−	+	−
		Ficus lutea Vahl.	+	+	−
		Ficus natalensis Hochst.	+	−	−
		Ficus religiosa L.	+	+	−
		Ficus sur Forssk.	+	−	−
		Ficus thonningii Blume.	+	−	−
		Ficus vogelii Miq.	+	−	−
Moringaceae	*Moringa*	*Moringa oleifera Lam*	+	+	−
Musaceae	*Musa*	*Musa sinensis Sagot ex Baker*	−	−	+
Myrtaceae	*Eucalyptus*	*Eucalyptus camaldulensis Dehnh.*	+	+	−
	Psidium	*Psidium guajava L.*	−	+	+
Nyctaginaceae	*Bougainvillea*	*Bougainville aglabra Chois.*	−	+	−
Oleaceae	*Ligustrum*	*Ligustrum japonicum Thunb.*	−	+	−
Oxalidaceae	*Averrhoa*	*Averrhoa carambola L.*	−	+	−
Rhamnaceae	*Zizyphus*	*Zizyphus mauritiana Lam.*	−	+	−
Rubiaceae	*Morinda*	*Morinda citrifolia L.*	+	−	−
Rutaceae	*Citrus*	*Citrus limon (L.) Burm.*	+	+	+
		Citrus reticulata Blanco	+	+	−
		Citrus sinensis (L.) Osbeck	−	+	−
Sapotaceae	*Chrysophyllum*	*Chrysophyllum cainito L.*	−	+	−
	Manilkara	*Manilkara zapota (L.) P. Royen.*	+	+	−
	Pouteria	*Pouteria torta (Mart. Radlk.)*	+	−	+
Sterculiaceae	*Cola*	*Cola cordifolia (Cav.) R.Br.*	−	+	−
	Theobroma	*Theobroma cacao L.*	−	+	−
Ulmaceae	*Trema*	*Trema orientalis (L.) Blume.*	+	+	−
Verbenaceae	*Gmelina*	*Gmelina arborea Roxb.*	+	+	+
	Tectona	*Tectona grandis L.*	−	+	−
	Vitex	*Vitex doniana Sw.*	−	+	−
Zygophyllaceae	*Balanites*	*Balanites aegyptiaca (L.) Delile*	−	+	−
33	72	89			

"+" presence and "−" absence.

3.2. Woody Vegetation Diversity

Analysis of variance showed that tree diversity varied significantly between cult places for Shannon and Heip evenness indices (**Figure 2**). However, cult places did not influence significantly Pielou evenness index. Parishes recorded highest diversity with Shannon index (2.2 ± 0.19), reflecting balanced species distribution and favorable ecological conditions. Cemeteries were associated with an important diversity with Shannon values (1.59 ± 0.13) compared to mosques (1.07 ± 0.36). In contrast, Mosques recorded the highest Eevenness (0.71 ± 0.12). These findings highlight the influence of habitat conditions and management practices on the ecological diversity of these sites.

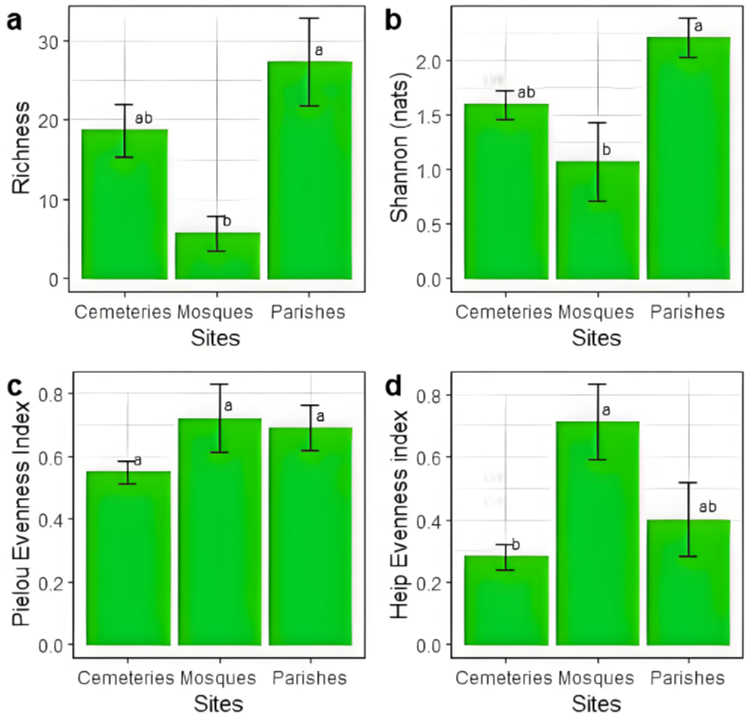

Figure 2. Floristic composition and diversity; richness (a), Shannon index (b), Pielou index (c) and Heip index (d) across cult places.

Bray-vurtis ecological distance reflected varying differences in vegetation species composition between cult places (**Table 2**). Mosques were more dissimilar with cemeteries (96.36%) and parishes (95.35%). The lowest ecological distance (72.55%) was recorded between cemeteries and parishes, with an important sharing species. There were differences in species composition of mosques compared to cemeteries and parishes.

Table 2. Bray-Curtis ecological distance between cult places.

	Cemeteries	Mosques
Mosques	0.9635659	
Parishes	0.725474	0.9534884

3.3. Structural Parameters

Height and regeneration rate varied significantly according to cult places (**Figure**

3). Trees were taller in mosques (16.28 ± 1.28 m), followed by cemeteries (14.49 ± 0.93 m) and parishes (11.31 ± 0.64 m). The taller trees in mosques likely represented mature ornamental species, while cemeteries displayed a mix of mature and regenerating vegetation.

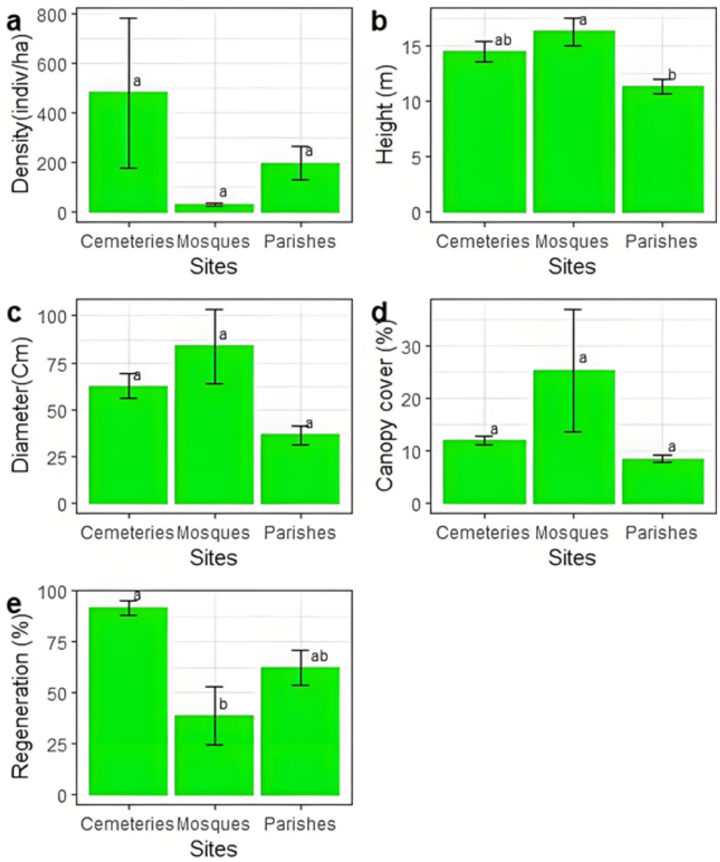

Figure 3. Comparison of structural parameters across cemeteries, mosques, and parishes.

Regeneration rates were significantly higher in cemeteries (91.69 ± 3.72 indiv/ha) compared to parishes (62.22 ± 8.56 indiv/ha) and mosques (38.82 ± 14.50 indiv/ha). The high regeneration in cemeteries reflected favorable conditions for recruitment, while mosques, with their focus on mature ornamental species, exhibit limited regeneration dynamics.

There were not significantly variations of diameter, density and canopy cover between cult places (Figure 3). In absolute value, mosques exhibited the larger trees (83.72 ± 20.09 cm) followed by cemeteries (62.4 ± 6.56 cm) and parishes (36.38 ± 5.29 cm). This suggested that while mosques tended to host larger trees, the overlap in variability reduced distinctiveness. The smaller diameters in parishes were consistent with younger stands. For the density, cemeteries recorded substantially greater density (482.26 ± 302.71 indiv/ha) than parishes (197.61 ± 67.14 indiv/ha) and mosques (32.34 ± 4.89 indiv/ha).

High variability (SE = 302.71) was observed in cemeteries. This variability indicated heterogeneity in vegetation cover across cemeteries, possibly influenced by spatial factors and management practices. Canopy cover varied from 8.48 ± 0.67 to 25.43 ± 11.65 m^2/ha according to cult places. The higher canopy cover was recorded in mosques (25.43 ± 11.65 m^2/ha) followed by cemeteries (11.99 ± 0.80 m^2/ha). The lowest cover was recorded parishes (8.48 ± 0.67 m^2/ha). The higher canopy cover in mosques corresponded with their larger trees, while lower canopy cover was associated the smaller and younger trees in parishes.

The trends across these structural parameters underscored distinct ecological roles and management practices in the three cult types. Cemeteries were characterized by dense and regenerating vegetation with high variability. Mosques were associated with adult, taller and larger trees, and higher canopy cover. Parishes represented an intermediate state with smaller and younger trees and moderate regeneration.

3.4. Distribution of Structural Parameters

3.4.1. Horizontal Distribution of Individuals

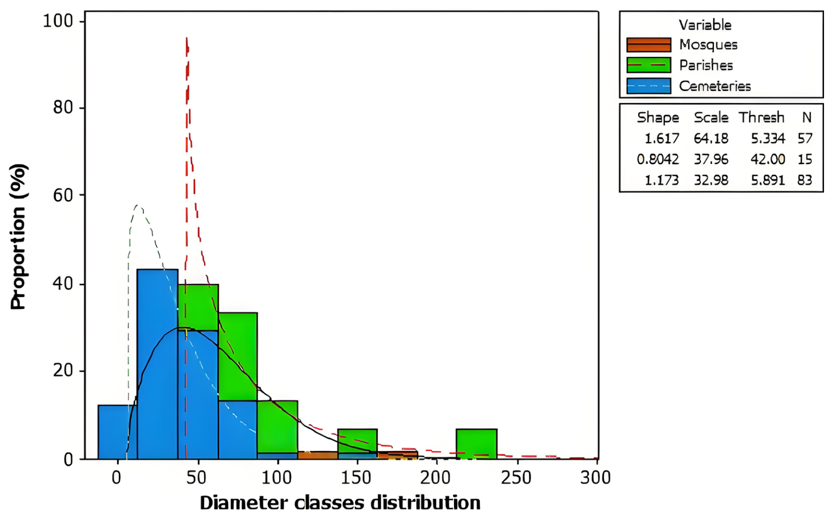

Figure 4. Diameter class structure of woody vegetation in cult places.

The analysis of horizontal distribution emphasized the shape parameter (a key indicator of distribution form) with scale and threshold parameters to highlight differences in vegetation structure and regeneration dynamics within these ecosystems. Different trends of horizontal distribution between cult places were observed (**Figure 4**). The shape parameter provides critical insights into the structural differences among the three cult places. The diameter class distribution for cemeteries followed a classic inverted J-shape, as evidenced by a shape parameter of 1.173. Cemeteries, with a shape parameter close to 1, reflected an actively regenerating population dominated by young vegetation. In contrast, the diameter distribution for mosques presents a flatter curve, with a shape parameter of 1.617. Mosques, with a shape parameter greater than 1, demonstrate a more even distribution of tree sizes, indicative of a mix of age classes but with constrained regeneration. The diameter class distribution for parishes exhibits a steeper inverted J-shape, as suggested by a shape parameter of 0.8042. Parishes, with a shape parameter less than 1, represent a population skewed heavily toward smaller trees, with limited representation of larger individuals. The scale and threshold parameters further refine this understanding by illustrating the variability and minimum tree sizes within each category. Cemeteries exhibit the most uniform and regenerative vegetation structure, while mosques display greater diversity but limited recruitment of young trees. Parishes appear to balance mid-sized tree retention with limited small-diameter representation.

3.4.2. Vertical Distribution of Individuals

The analysis of vertical distribution revealed a variation in shape according to cult places (**Figure 5**). For cemeteries, the shape parameter(1.173) is a moderately skewed distribution. This value suggested a preponderance of smaller height classes, reflecting an actively regenerating population where young individuals dominate. The distribution approximated an inverted J-shape, characteristic of ecosystems experiencing continuous recruitment. The scale parameter (32.98) indicated that the spread of heights is moderate, with most individuals concentrated in the smaller classes. The threshold value (5.891) was low, confirming the presence of very young vegetation. This pattern reflects a dynamic ecosystem with minimal disturbance, allowing for natural regeneration and a steady influx of smaller individuals into the population.

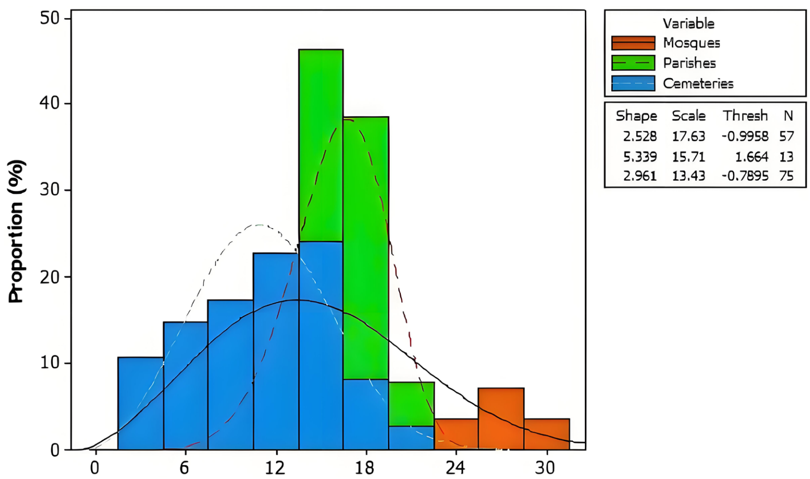

Figure 5. Height class distribution of woody vegetation in cult places.

The vegetation in mosques displayed a distinct height class distribution with a shape parameter of 1.617, indicating a less steep inverted J-shape. This higher value signified a more balanced population, where small and medium-sized individuals were both represented, with a noticeable proportion of taller vegetation. The scale parameter (64.18) highlights a broader spread of height classes, while the low threshold (5.334) confirmed the presence of young plants. However, compared to cemeteries, the higher shape parameter suggested limited recruitment of new individuals and possibly a greater focus on preserving larger, established vegetation. In parishes, the height class distribution was characterized by a shape parameter of 0.8042, which denotes a more pronounced skew toward smaller classes than either cemeteries or mosques. This low shape parameter implied that smaller individuals dominate, with relatively few taller individuals in the population. The scale parameter (37.96) indicates a moderate range of heights, while the high threshold (42.00) suggests that the smallest individuals in this category are already quite mature, with very young vegetation largely absent. This pattern may reflect a controlled management strategy, where taller, mid-sized vegetation is preserved while young regeneration is limited.

3.5. Community Characteristics and Relationship between Vegetation Variables

Principal Component Analysis (PCA) grouped the woody vegetation of cult places based on their characteristic similarities. The first component (PC1) explained 42.0% of the variance, while the second component (PC2) accounted for 24.5%, cumulatively representing 66.5% of the total variability (**Figure 6(a)**). This strong contribution from the two axes provided a clear visualization of the relationships between the clusters (groups) and vegetation variables, offering a solid foundation for analyzing the observed groupings. PCA discriminated four clusters or groups. The groups formed by the analyzed sites revealed distinct ecological dynamics. Group 1, composed of cemeteries (CBEL, CKAN, CSAN) and a parish (PND), was characterized by high species richness, elevated density, and high diversity indices (Shannon, Simpson). These features reflect densely populated, diverse, and often well-preserved habitats. For example, CKAN is particularly influenced by density and richness, emphasizing a dense and varied vegetation structure. Group 2, comprising the parish SAP and the mosque MP, was dominated by structural variables such as height, tree diameter, and the Pielou evenness index. This group represents sites where mature trees dominate, although species diversity is moderate. SAP stands out due to a strong contribution from structural characteristics, likely a result of a homogeneous but well-developed vegetation profile. Group 3, which included parishes (PSA, PSB) and the cemetery CKE, formed a transitional cluster between Groups 1 and 4. It was characterized by moderate density and intermediate diversity indices, indicating balanced habitats that are neither overly open nor excessively dense, with relatively homogeneous diversity. Group 4, consisting of mosques (MGD, MK, MKAD), was distinguished by specific structural variables like crown diameter but is generally scattered and weakly influenced by other parameters. These sites represented highly anthropized or environmentally stressed habitats, which limit diversity and regeneration.

The correlation matrix highlighted significant relationships among several ecological variables (**Figure 6(b)**). For instance, species richness strongly correlates with the Shannon index (0.96), suggesting that species-rich habitats also exhibited balanced diversity. Similarly, height and tree diameter were highly correlated (0.87), reflecting the dominance of mature trees in some groups, particularly SAP and MP in Group 2. Additionally, the correlation between the Pielou index and

Shannon index (0.78) underscored that habitats with evenly distributed diversity tended to be more balanced, as seen in Group 1.

In contrast, some variables display inverse or limited relationships. For example, density shows a weak negative correlation with species richness (−0.18), implying that in highly dense sites like CKAN (Group 1), interspecific competition may reduce diversity. Additionally, crown diameter exhibits minimal correlation with other parameters, indicating its limited influence in groups dominated by cemeteries and parishes.

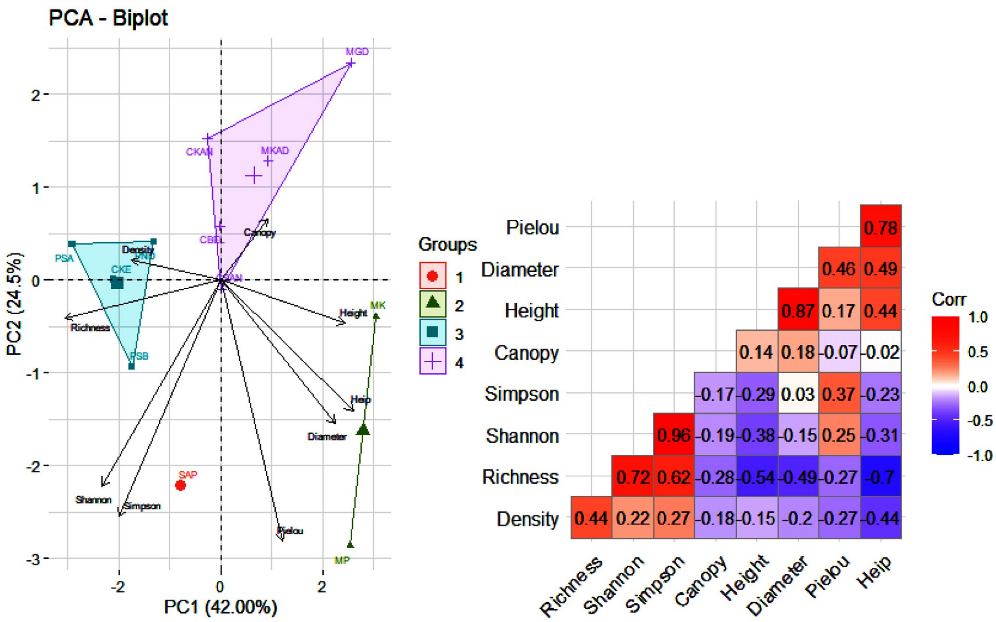

Figure 6. Characteristics of vegetation community (a) and relationship between vegetation parameters (b) in cult places of Ziguinchor City.

CBEL = Belfort Cemetery; **CKAN** = Kandialang Cemetery; **CKE** = Kénia Cemetery; CSAN = Santhiaba Cemetery; **MGD** = Grand Dakar Mosque; **MK** = Kandé Mosque; **MKAD** = Kadior Mosque; **MP** = Mosque of Peace; **PND** = Notre Dame Parish; **PSA** = Saint Augustine Parish; **PSB** = Saint Benedict Parish; **SAP** = Saint Anthony of Padua Parish.

4. Discussion

4.1. Floristic Diversity

The study of woody vegetation in worship sites within the Ziguinchor commune identified 86 woody species distributed across 70 genera and 32 families. Although this floristic richness is lower than that reported by [11], the discrepancy may stem from differences in sampling methodologies, the number of survey plots, and the size of the studied ecosystems. [27] Dasylva *et al.* (2017) recorded 90 woody vegetation species belonging to 79 genera and 35 families in Ziguinchor peri-urban area. These cult places were richer in species than the *E. guineensis* agroforestry parks in lower Casamance which recorded 63 woody species divided into 52 genera and 24 families [28] (Gomis, 2016).

The dominant families vary by site type. In cemeteries, the *Moraceae* (25.64%)

and Fabaceae (17.95%) are the most represented, contrasting with findings by [29], where *Apocynaceae* and *Fabaceae* dominated cemeteries in Soumbédioune and Bel-Air. In mosques, the *Arecaceae* and *Euphorbiaceae* are equally represented (14.29% each). Meanwhile, parishes are dominated by the *Fabaceae* (20.97%), followed by the Moraceae (8.06%). These results partially align with [11], who identified *Fabaceae*, *Moraceae*, *Euphorbiaceae*, and *Apocynaceae* as the main families in Ziguinchor.

Diversity indices highlight notable differences between the worship sites. Cemeteries exhibit the highest Shannon and Simpson indices, reflecting high biodiversity and balanced species distribution. Their high density (532 individuals/ha) underscores abundant woody vegetation. Parishes, while moderately species-rich, exhibit slightly lower diversity indices, remaining comparable to cemeteries. In contrast, mosques have low diversity indices, indicating reduced biodiversity and dominance by a few species.

Additionally, 54 characteristic species were identified: 35 in parishes, 17 in cemeteries, and only two in mosques. The limited diversity in mosques may be attributed to biodiversity management and conservation practices. Lastly, six indifferent species were found across all worship sites.

4.2. Structural Parameters

4.2.1. Density

Cemeteries have the highest vegetation density (532 individuals/ha), followed by parishes (465 individuals/ha), with mosques showing the lowest density (198 individuals/ha). These Cemeteries and parishes recorded the highest densities of woody species than in Cobitène (136.90 ± 43.26 ha) and Diéfaye (393.78 ± 148.09 ha) in Ziguinchor peri-urban area [27] (Dasylva, *et al.*, 2017). This pattern suggests that cemeteries and parishes benefit from management practices promoting natural regeneration and habitat preservation.

4.2.2. Basal Area and Canopy Cover

Basal area also varies significantly across worship sites. Mosques have the highest mean basal area (20.45 m^2/ha), followed by cemeteries (6.37 m^2/ha) and parishes (1.24 m^2/ha). The low basal area in parishes reflects the predominance of small-diameter individuals. Regarding woody cover, cemeteries (78.52 m^2/ha) and parishes (72 m^2/ha) outperform mosques (19.47 m^2/ha). The Cobiténe and Dièfaye valleys had higher canopy cover with 862.59 ± 270.27 m^2/ha and 1976.08 ± 1118.80 m^2/ha respectively than cult places in Ziguinchor city [27] (Dasylva, *et al.*, 2017). This high cover in cemeteries and parishes is attributed to the presence of large-crowned species such as *Ceiba pentandra*, *Combretum cordifolia*, and *Adansonia digitata*. These values far exceed those reported by [30] in fields and fallows at Keur Birame (7.32%) and Saré Yorobana (20.90%), emphasizing the ecological significance of worship sites as reservoirs of woody biomass and biodiversity.

4.2.3. Regeneration

Cemeteries and parishes exhibit high regeneration rates, likely due to the absence of intense logging, deforestation, and frequent weeding. This dynamic is bolstered by prolific sprouting from species like *Guiera senegalensis* (*Combretaceae*) in cemeteries and *Combretum micranthum* in parishes. These species, known for their winged fruits, facilitate efficient wind dispersal [31]. Conversely, mosques show limited regeneration, likely due to frequent maintenance practices that remove young shoots, hindering renewal.

4.2.4. Horizontal Distribution

The horizontal distribution reveals a dominance of young individuals (diameters <50 cm) in cemeteries and parishes, reflecting active natural regeneration. These findings align with [32], who reported similar trends in cemeteries in Soumbédioune and Bel-Air. In contrast, mosques are characterized by aging vegetation, with a low proportion of young individuals.

4.2.5. Vertical Distribution

Vertical distribution also varies across sites. Cemeteries are dominated by individuals with heights between 12 - 18 m, with fewer in higher height classes (24 - 30 m). Parishes exhibit a bell-shaped structure typical of even-aged stands, with most individuals in medium height classes. Conversely, mosques are dominated by taller individuals (>14 m), reflecting the absence of younger trees, often removed during routine maintenance to enhance accessibility and space.

5. Conclusions

Cult places in Ziguinchor were rich and diversified. The tree diversity varied according cult places. Cemeteries and parishes had higher diversity compared to mosques.

Dominant families varied according to cult places: *Fabaceae* and *Moraceae* dominated in cemeteries and parishes, while *Arecaceae* and *Euphorbiaceae* were prevalent in mosques. Tree diversity and structural parameters varied according to cult places. Parishes and cemeteries recorded higher diversity compared to mosques. Mosques were characterized by higher density and canopy cover and taller trees. Parishes and cemeteries recorded larger trees and higher regeneration rate. The cult places play an important ecological role in biodiversity conservation. This biodiversity provides various ecosystem services, including local flora conservation, ecological regulation, and food resources for certain communities. These habitats also play a critical role in environmental functions such as carbon sequestration, air quality improvement, and microclimate regulation.

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Conflicts of Interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

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